IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

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3 Park Avenue
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23 February 2006

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(Revision of
IEEE Std 336-1985)

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IEEE Std 336™-2005
(Revision of
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IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities

Sponsor

Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society

Approved 26 January 2006

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Abstract: This guide provides considerations for the pre-installation, installation, inspection, and testing of Class 1E power, instrumentation, and control equipment and systems of a nuclear facility. This guidance is applicable to initial construction, modification (backfit), and maintenance activities. This guide does not apply to periodic testing.
Keywords: Class 1E, configuration management, constructability reviews, functional testing, inspection procedures, multi-unit, nuclear facilities, plant design bases, pre-construction inspection, pre-construction testing, pre-installation inspection, pre-installation testing, post-installation inspection, post-construction testing, post-maintenance testing, post-modification testing, test plans, test procedures

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Introduction

This introduction is not part of IEEE Std 336-2005, IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities.

This guide was originally published as a standard, and it set forth requirements for installation, inspection, and testing of important instrumentation and electric equipment in a nuclear power generating station during its construction phase. This standard was prepared by the IEEE in response to a request by American National Standards Committee N45 on Reactor Plants and their Maintenance. The N45 committee was chartered to promote development of standards for location, design, construction, and maintenance of nuclear reactors and plants embodying nuclear reactors, including equipment, methods, and components specifically for this purpose.

In May 1969, the IEEE Joint Committee on Nuclear Power Standards (JCNPS) established an ad hoc committee on Installation, Inspection, and Testing of Electric and Instrumentation Equipment. The purpose of this committee was to prepare a standard for general industry use that would define requirements for installation, inspection, and testing of instrumentation and electric equipment necessary to ensure attainment of a safe and reliable nuclear power generating station. The ad hoc committee was composed of representatives of key segments of the nuclear industry, including utilities, reactor suppliers, construction contractors, component manufacturers, and consultants.

In 1977, the standard was revised to provide clarity and simplification. In 1979, the standard was again revised to expand the scope to include operating plant modifications that are comparable in nature and extent with those related activities occurring during initial construction of the station. Subcommittee 8 of the Nuclear Power Engineering Committee (NPEC) developed these revisions.

In 1985, this standard was then revised to allow application of the requirements to include nuclear facilities other than nuclear power generation stations. Nuclear facilities include facilities for power generation, spent fuel storage, waste storage, fuel processing, plutonium processing, and fuel fabrication.

In 2003, the Nuclear Power Engineering Committee directed its Working Group 3.1 to convert IEEE Std 336™-1985 from a standard to a guide (to allow more flexibility for selective guidance than mandatory requirements), to incorporate “lessons learned” from industry (in particular, for post-modification and post-maintenance testing), and to change the format to be more user-friendly.

Suggestions for improvement gained in the use of this guide will be welcomed. They should be addressed to:

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Working Group 3.1 would like to acknowledge and commemorate the instrumental and dedicated efforts of our colleague Surin Dureja to the completion of this revision. We regret his unfortunate passing shortly after this revision was approved by the IEEE Standards Committee.

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IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities

1. Overview

1.1 Scope

This guide provides considerations for the pre-installation, installation, inspection, and testing of Class 1E power, instrumentation, and control equipment and systems of a nuclear facility while in the process of installing, inspecting, and testing during new construction, modification, and maintenance. This guidance is applicable to initial construction, modification (backfit), and maintenance activities. This guide does not apply to periodic testing.

1.2 Purpose

The purpose of this guide is to identify the activities, instructions, and attributes that may be considered in the process of installing, inspecting, and testing during new construction, modification, and maintenance for Class 1E power, instrumentation, and control equipment at nuclear power stations.

Changes to this guide are intended to

— Review and consider “lessons learned” from industry (in particular, for post-modification and post-maintenance testing).

— Provide a more comprehensive, organized “user-friendly” format.

— Review and consider any other related user feedback.

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1.3 Applicability

The recommendations set forth in this guide apply to the work of organizations that participate in the installation of new equipment or equipment modifications, inspections and testing, or modification of power, instrumentation, and control equipment and systems in a nuclear facility from the time the equipment is turned over for installation until it is declared operable for service.

Although they are related to the above equipment and systems, this guide does not provide specific recommendations for the following:

a) Installation, inspection, and testing of welds
b) Cleaning and flushing of instrument sensing lines
c) Aligning or verifying alignment of rotating equipment
d) Verifying structural integrity of equipment supports
e) Activities governed by Section III of the ASME Boiler and Pressure Vessel Code[1]
f) Periodic testing and maintenance following initial operation
g) Receipt inspection and testing
h) Non-destructive examination, when required

1.4 Responsibility

The organization invoking this guide is responsible to identify equipment and systems to which this guide applies. The planning operations stipulated in 4.3 should specify inspections and tests to be performed on identified equipment and systems consistent with this guide. Establishment of practices and procedures and providing resources, in terms of personnel, equipment, and services, to implement the requirements of this standard may be delegated to other organizations. This delegation should be documented. The organization invoking this guide should retain responsibility for the overall effectiveness of the installation, inspection, or testing activities.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI/ANS 3.2-1999, Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants.[2]

ANSI/ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facilities Applications.[3]

ASME Boiler and Pressure Vessel Code.[4, 5]

[1] Information on references can be found in Clause 2.
[2] ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).
[3] ANSI/ASME publications are available from the American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10016-5990, USA (http://www.asme.org/).
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10CFR 50.2, Definitions.[6]

IEEE Std 338™-1987, IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.[7, 8]

IEEE Std 603™ -1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

INPO 87-028 (Dec. 1994), Post -Maintenance Testing.[9]

3. Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms*[10] should be referenced for terms not defined in this clause.

3.1 construction tests: Tests performed during and after equipment installation in the construction or configuration change phase to demonstrate adequacy of workmanship. These tests are usually static in nature and provide verification of functionality at the component level. Typical construction tests may include insulation resistance testing, calibration checks, and mechanical testing. Construction tests are typically completed before placing systems and equipment in specific configuration/alignment for more complex system-level testing.

3.2 equipment/system functional testing: Functional testing is verification or validation that the equipment can meet its design and functional requirements (i.e., performance requirements otherwise known as acceptance criteria). System testing verifies that all parts of a system work well together, as designed.

3.3 plant design bases: Information that identifies specific functions to be performed by a structure, system, or component of a facility and specific values or ranges chosen for controlling parameters as reference bounds for design. These values may be as follows: (**A**) Restraints derived from generally accepted state-of-the-art practices for achieving functional goals. (**B**) Requirements derived from analysis (based on calculations or experiments) of the effects of a postulated accident for which a system, structure, or component (SSC) should meet its functional goals. (10 CFR 50.2)

3.4 pre-installation inspection/tests: Inspections and tests, including factory acceptance testing, performed to demonstrate the functionality and intended design function of an SSC. This could also be achieved by receipt inspection testing for dedication of commercial grade equipment. Testing verifies that design requirements are met. Testing typically verifies extremes of environmental specifications and ranges of input.

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[5] A version of this reference consistent with the nuclear facility's licensing basis should be used. Contact ASME in regard to an appropriate archival service for superseded codes.
[6] CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (http://www.access.gpo.gov/).
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3.5 post-modification/maintenance test (PMT): Appropriate testing performed after modification or maintenance or to verify a particular piece of equipment or system performs its intended function based on design criteria. When maintenance or modification is performed, it is critical to show by testing that design bases and license design bases requirements and acceptance criteria are met for existing design (post-maintenance testing) or for the modified design (post-modification testing). Where applicable, PMT also is used to collect baseline data for equipment performance monitoring. (INPO 87-028)

3.6 post-modification/maintenance test plan (PMTP): A tool (either electronic or paper) used to summarize required post-modification/maintenance testing and that verifies plant design bases have been maintained or establishes a new baseline. Response criteria established by the configuration change process are verified by testing the modified equipment or system.

3.7 surveillance testing: A test of installed equipment or systems required to satisfy licensing requirements. (INPO 87-028)

4. General considerations for initial construction, modification, and maintenance

4.1 General

Measures should be established and implemented for planning and control of installation, inspection, and testing activities to verify conformance to specified requirements. Considerations in 4.2 – 4.11 should be used to provide these measures.

During the initial construction phase and performance of modifications, this guide should be used in conjunction with applicable portions of ANSI/ASME NQA-1-2000. During the operations phase, this guide should be used with applicable portions of ANSI/ANS 3.2-1999.

4.2 Configuration management

The following documents should be controlled for establishing installation and test requirements:

a) Qualification documentation from as-tested configuration
b) Material source testing reports
c) Procurement specifications.
d) Installation specifications
e) Manufacturers' instructions
f) Installation drawings
g) Existing system/equipment removal instructions, if required

These documents determine the installation criteria for the equipment or system. Installation criteria are to be maintained during installation and verified by testing or inspection.

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4.3 Planning

4.3.1 General

Documented plans should be developed that define installation, inspection, and testing activities and systematic, sequential progression of operations for each item or system; responsibilities of parties concerned for each activity; and measures employed to preserve the quality of equipment.

Planning should take into account the need for preparation and control of procedures and work instructions necessary to comply with requirements for installation, inspection, and testing of equipment and systems.

Planning should include a review of system and equipment specifications, performance history, construction work plans, and schedules to ensure that installation, inspection, and testing activities have been incorporated and that they can be accomplished as specified. Planning should consider any equipment protection requirements like covers, filters, and high voltages.

Boundaries of the retrofit should be predetermined for configuration changes to a system or component that is operational. Planning should include appropriate preparations necessary to safely add, modify, or remove the system or component in question. Fluid, electrical, structural, and radiological interfaces should be predetermined to properly define the scope of the configuration change. When required, such plans should include a removal phase to prepare for the installation phase.

4.3.2 Construction/Modification plan (CMP)

A CMP (including removal, when required, and installation plan for a modification) should be developed for control of the process through final testing. CMP complexity depends on the scope of the project that can range from new plant construction to a simple component change. For personnel safety, equipment protection, and nuclear safety, a formal process is required regardless of project complexity. Scheduling should be an essential part of the plan.

4.3.3 Post-modification/maintenance test plan (PMTP)

PMTP complexity depends on project scope.

The PMTP establishes the prerequisites, sequence, and specific test and inspections required for both installation and post-modification testing. PMTP typically requires procedures for each test.

PMTP establishes controls necessary during testing to prevent equipment damage, ensure personnel safety, and validate design and license bases.

4.4 Closeout tracking

This document/electronic database tracks the status of the various installation plan steps and prerequisites for the next step. The PMTP and CMP can be coordinated by this document, which controls sequencing and document status of PMTP and CMP requirements.

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4.5 Procedures

Procedures should be prepared, maintained up-to-date, and used to control activities associated with installation, inspection, testing, and modification. These procedures may be in the form of drawings, instructions, or manuals and should consider the following:

a) Removal (if required) and installation specifications

b) Inspection and test objectives

c) Precautions to avoid equipment or system damage during removal, installation, testing, or inspection

d) Inspection and test equipment required or recommended

e) Sequence of tests

f) Sequential actions to be followed

g) Personnel safety

h) Equipment safety requirements

i) Test prerequisites

j) Appropriate approvals

k) Suitable documentation for reporting data

l) Provision for identification of test equipment and date of next required recalibration (where required)

m) Inspection and test acceptance limits

n) Performance and developmental references

o) Manufacturer's instructions

4.6 Measuring and test equipment

Measuring and test equipment used to determine compliance with specifications should be controlled and calibrated in accordance with approved procedures.

4.7 Personnel qualification

Personnel performing the verifications required by this guide should be qualified according to an approved training and qualification program.

4.8 Test data evaluation

Procedures should be established for processing inspection results and for analyzing and evaluating test data. These procedures should include requirements for inspection and test data to be reviewed or evaluated against acceptance criteria. The data from testing should be analyzed (evaluated) to verify completeness, achievement of objectives, and correct operation of equipment and systems.

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4.9 Results

Inspection and test results should be documented in a suitable test report or data sheet. Each report should identify

a) Person performing the test

b) The item to which it applies

c) The procedures or instructions used, with the revision number

d) An evaluation of the acceptability of the results

e) Unanticipated conditions encountered, including nonconformance

f) Completion date

4.10 Nonconforming items

Procedures should be established for identifying, documenting, and obtaining authorization for resolving each nonconforming situation. Defects, deficiencies, discrepancies, or other nonconforming situations should be resolved in accordance with established procedures.

4.11 Records

Approved procedures and reports of personnel qualifications, test equipment calibration, inspections, and testing should be maintained as quality records.

5. Pre-installation constructability review

The following, which relates to the specific equipment to be installed, should be available for review at the construction site in legible form:

a) The latest applicable approved-for-construction drawings.

b) Installation specifications, procedures, or special work instructions to include removal scope and instructions, if required. Removal instructions should include appropriate plant conditions and methods of isolating the system or component to ensure a safe condition for equipment and personnel.

c) Identification of materials and equipment according to the latest approved-for-construction drawings, equipment lists, and specifications.

d) Documentation of protective measures taken during storage and handling.

e) Documentation of visual examination of materials and equipment for damage, corrosion, contamination, and condensation.

f) Documentation showing qualification reports and documents have been reviewed and approved for the application.

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6. Installation/Construction

6.1 Equipment placement

Equipment should be located, installed, assembled, and connected in strict compliance with the following:

a) Latest approved-for-construction drawings
b) Engineering instructions
c) Engineering specifications and procedures for installation

6.2 Engineering procedures and specifications

Engineering procedures and specifications should be applied to

a) Cable pulling
b) Cable splicing
c) Cable terminating
d) Cable and instrument sensing line routing, including maintenance of required separation between redundant systems (consideration should be given for electromagnetic interference)
e) Tagging or identifying various items of particular concern to the retrofit circumstance, including cables and temporary conditions
f) Installing electrical and instrumentation penetration assemblies and ensuring the integrity of the containment seals
g) Installation of fire stops and fire barriers
h) Installation of instrumentation piping or tubing
i) Mounting and supporting of equipment
j) Removal of temporary shipping supports and hold-down bolts
k) Installation of environmental and pressure seals
l) Calibration of measuring and test equipment
m) Functional testing of installed equipment

6.3 Verification during installation

Verification during installation should include tests performed according to specification and procedure requirements. Verifications can generally be performed by worker self-checks. In-process inspections are critical to the success of the installation where specific parameters must be satisfied to properly continue the work. Dimensional tolerances or electrical values should be verified to be satisfactory before the next step is performed. For example, bearing clearances and embedded bearing temperature monitoring sensor insulation values should meet specified tolerances before completing assembly because they become inaccessible. A fluid connection fit-up should also meet dimensional tolerances before final bolting or

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welding of the union. Also, self-checks performed during installation should include verification of the following:

a) Use of correct tools with up-to-date calibration.

b) Correct equipment is being worked, using correct documents and procedures.

c) When necessary, procedural steps are being followed in the order specified to ensure proper assembly of the equipment.

d) Personnel and industrial safety is properly considered.

e) Adequacy of general housekeeping in and around the work area.

6.4 Post-installation inspections

Independent inspections should be performed to verify equipment is assembled, located, installed, and connected in compliance with latest approved-for-construction drawings, installation specifications, and procedures.

When testing integrated electrical control or instrumentation systems, for which plant design calls for interconnection between existing and new systems, care should be exercised to prevent tripping or otherwise disturbing operation of equipment or systems associated with existing unit(s).

Inspections should include verification of

a) Leveling, orientation, and alignment

b) Clearances and tolerances

c) Location, support, and routing of cables and sensing lines

d) Tightness of connections and fasteners

e) Freedom of movement

f) Polarity

g) Grounding and shielding terminations

h) Fuse protection

i) Redundant circuit separation

j) Fluid levels and pressures

k) Absence of leaks

l) Physical integrity

m) Identification

n) Equipment rating

o) Fire stops and fire barriers

p) Installation of mountings and supports

q) Recommended lubricant

r) Lubrication of bearings

s) Environmental and pressure seals

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6.5 Inspections of temporary conditions

All temporary conditions, such as jumpers, lifted leads, bypass lines, and temporary setpoints, should be clearly identified so they can be removed or properly set before placing the items in service. Temporary conditions are often a significant attribute in backfit installations to isolate the subject system or component from the rest of the plant. Furthermore, temporary jumpers, test connections, and bypass lines are often required to establish appropriate conditions for testing the new equipment before normal connections to the plant.

7. Testing

7.1 General

Several forms of testing can be used to assure compliance with nuclear facility operational and design requirements. These forms of testing are described in 7.2 – 7.8.

7.2 Material source testing

Manufacturers' tests on fabricated items may be accepted for equipment not disturbed during the construction phase. Tests performed during installation should be those specified in the planning in 4.3.

7.3 Electrical tests

Various electrical tests that can be performed as required, are described as follows:

a) Tests that ascertain circuit continuity, proper grounding, insulation resistance, and short circuits, correct polarity and correct direction of rotation.

b) Tests that ascertain electromagnetic compatibility with adjacent equipment by controlling electromagnetic emissions and verifying immunity to electromagnetic interference or radio-frequency interference expected in the immediate area.

c) Tests that ascertain proper phasing and functioning of equipment, including indicating meters, recorders, transducers, digital controllers, targets and lamps, annunciators and alarms, controls, interlocks, protective relays, and breakers.

d) Voltage breakdown tests on fluid insulation.

e) Hi-Pot or partial discharge tests, as specified. (When Hi-Pot tests are performed, the manufacturers' recommendations should be considered.)

7.4 Physical and chemical tests

Various physical and chemical tests that can be performed as required, are described as follows:

a) Chemical analysis of fluids for oxygen, moisture content, and purity

b) Radiation testing to confirm the radiation sensors and controlling devices are properly functioning

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7.5 Mechanical tests

Leak or flow tests should be performed to demonstrate proper operation of electrical, instrumentation, and control equipment. As a minimum, tests should be developed for pressure sensing and transmitting devices operating in steam, hydraulic, or pneumatic interconnecting piping or tubing and associated instruments to ascertain they can withstand system pressure ratings.

Electrical components of pressurized systems, such as heat exchangers, circulating systems, and actuating systems, should be tested. Electrical and instrumentation components for containment penetrations should also be tested.

7.6 Equipment functional tests

Installed equipment and systems should be tested to demonstrate that they have been installed in accordance with design requirements and that their operation is satisfactory in accordance with the test requirements. Functional test requirements should be based on performance requirements established by the equipment's design or design modification.

Temporary electrical connections, temporary piping sections, abnormal chemical solutions, setting of devices, or temporary blocking should be verified and documented in accordance with an approved test configuration. In these instances, a notice stating the temporary test conditions and reference to the appropriate test procedure should be tagged. Normal system readout devices and permanently installed transducers should be used as far as possible to monitor the operation.

Where the installed equipment is not adequate for the purpose of conducting tests, special measuring instruments and simulating devices should be used as noted in the test procedure. Test equipment used should have adequate capacity, tolerance, and up-to-date calibration. The functional test should also check for inappropriate equipment responses such as vibration, fluid leaks, elevated noise levels, and electromagnetic interference. Inappropriate responses should be evaluated and corrected as required.

7.7 System tests

Tests should be performed to verify all parts of a system properly coordinate with each other. Tests should demonstrate required independence and dependence of subsystems. Testing that has preceded final integrated system testing should be reviewed with particular attention given to equipment tests that demonstrate functional or operational results. Functional test requirements should be based on performance requirements established by the equipment's design or design modification.

When these tests serve as prerequisite or a part of the test completed system, construction activities that may have affected the results should be reviewed. The final construction-phase testing should be made with all equipment of subsystems complete, except where operation requires temporary electrical connections, piping sections, or structural supports be installed to make the tests.

7.8 Post-modification/maintenance testing plan (PMTP)

Post-modification and post-maintenance testing should ensure that the equipment or system operates within the nuclear facility's design bases and in accordance with the performance requirements established by the equipment or system's design. The PMTP should establish the prerequisites, sequencing, and a schedule of tests and inspections for post-installation.

When manufacturers' tests or calibrations cannot be accepted, tests should be performed to demonstrate that the installed equipment is in an acceptable condition to be energized. Tests and shakedown runs should be made on energized systems, when necessary, to evaluate operation and to properly condition for service

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(for example, seating of brushes or bearings, stabilization of instrumentation and burn-in of electronic devices). Tests should be made to ensure instrumentation and control channels are properly calibrated. If calibration is dependent on location or orientation, calibrations should be made with devices in their normal positions. The level of testing will depend on the complexity of the SSC. Testing should ensure equipment being worked will perform its intended design function and, conversely, ensure associated circuits can still perform their design function.

Tests should be performed to determine proper operation over the required range of the device. Particular attention should be given to verifying independence and dependence, as appropriate, of the systems' elements. Document the identity of the person who performed the calibration. On the items that require calibration, enter the date of the next required calibration.

PMT is performed to

a) Verify components and systems are capable of performing their intended function.
b) Ensure deficiencies are corrected.
c) Ensure new deficiencies have not been created.
d) Collect baseline data for equipment performance monitoring.
e) Document post-maintenance test performance.

A post-maintenance procedure should be established to

a) Assign responsibilities related to specifying test requirements, conducting tests, and reviewing test results.
b) Provide guidance for determining the scope of PMTs.
c) Provide instructions for implementing PMTs.
d) Provide direction for control of PMT.
e) Provide the process flow for offline work packages that contain ASME Section XI packages.

8. Supplementary provisions for multi-unit facilities

8.1 General

Subclauses 8.2 through 8.5 apply to construction activities at nuclear facilities where one or more units are already operating or have reached a stage in their construction where the fuel has been loaded in the reactor and associated systems have been energized. Different unit boundaries should be clearly identified, and equipment identifying different units should be clearly tagged. The following measures in 8.2 – 8.5 should be taken in addition to the provisions defined elsewhere in this guide.

8.2 Planning and preparation

Instructions, procedures, and drawings should be prepared to control installation, inspection, and testing activities at interfaces with the unit on which installation and testing activities are in progress. Testing at interconnected, multi-unit sites should include the following:

a) The areas of interface between different units
b) Access control and authority for work at these interface areas

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8.3 Work tagging considerations

Equipment or systems associated with existing unit(s), which are electrically energized or charged with pressurized or radioactive fluids and which are in the vicinity of the construction activity associated with the unit on which installation and testing activities are in progress, should be properly tagged or identified. Shared equipment should be clearly labeled as such, and other equipment should be clearly labeled by unit.

8.4 Protection of existing unit(s)

Suitable protective barriers should be erected, where needed, to prevent damage to equipment or systems associated with existing unit(s).

Unless expressly indicated as being available for future use on applicable approved-for-construction drawings or installation specifications, spare capacities available in the existing facility, such as in cable raceways or panelboards, should be used only after appropriate engineering evaluation. This does not prohibit authorized temporary use of spare capacities.

8.5 Common area restriction

When working in an area common to two units, such as the cable spreading room, control room, or radioactive waste building, care should be exercised on non-operating equipment or systems. This is to avoid interference with operating facilities and to maintain required separation, where appropriate, between equipment and systems associated with the unit on which installation and testing activities are in progress.

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